Global Livestock CRSP

A New System to Forecast Near-Term Forage Conditions for Early Warning Systems in Pastoral Regions of East Africa

Robert Kaitho, Jerry Stuth, Jay Angerer, Abdi Jama, William Mnene, Margaret Kingamkono, Joseph Ndungu, Angello Mwilawa, Jane Sawe, Steven Byenkya, Elizabeth Muthiani, and Ezekiel Goromela

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LEWS has developed a new forage forecasting technology that provides a comprehensive view of emerging forage conditions, as well as 90-day forecasts updated every 10 days. Predicting spatial forage availability will make it possible for pastoralists to assess impending livestock mortality by kind and class of animal and decline in milk production. With the new system, pastoralists will have more flexibility in decision-making, leading to timely de-stocking strategies and an assurance of greater ecosystem integrity. The primary goal of the GL-CRSP Livestock Early Warning System Project (LEWS) is providing pastoral communities and supporting organizations with timely and high-value assessments of emerging forage conditions. Information on current trends in forage on-offer to livestock and the rate of change for conditions across East Africa can be provided by projecting forage conditions from computer models (driven by satellite-based weather data representing points on the ground) and coupling those projections with corresponding NDVI satellite forage greenness data. The forecasting procedure analyzes and projects equally spaced univariate time series data, transfer function data, and intervention data using an AutoRegressive Integrated Moving-Average (ARIMA) model. This approach predicts grazed standing crop of forage in a response time series as a linear combination of its own past values (modeled and NDVI data), past errors (shocks), and current and past values of other time series. Projections of 30, 60, and 90-day forage standing crops resulted in R^2 greater than 0.93, 0.81, and 0.71 with standard errors of prediction of less than 141, 206, and 259 kg/ha of available forage, respectively. This methodology is a powerful new mechanism for decision makers to identify emerging hot spots that may be difficult to perceive, and determine if they are going to recover or worsen with a progressive 90-day analysis window. The forecasts are well within normal sampling error, indicating that this new tool is valuable for predicting near-term forage response.

Background

The Livestock Early Warning System (LEWS) project has been developing a monitoring system to assess emerging trends in forage supply and animal condition on rangelands in Ethiopia, Kenya, Tanzania, and Uganda. Spatial sampling frames are established using climatic clustering techniques overlain with thematic layers for livestock and rural human population densities. Over 300 monitoring sites have been set up in nine zones across the region, covering approximately 50,000 square kilometers, each with minimum of 30 monitoring points. For each geo-referenced monitoring point, a multiple species grazingland plant growth model (PHYGROW) is parameterized with ground-collected data (soil profile, plant community, and grazing rules). The model is then run every ten days with current METEOSAT satellite daily weather data (http://cnrit.tamu.edu/rsg/rainfall/ranfall.cgi) (derived by Xie and Arkin, 1998; Grimes et al.,1999) to determine standing crop of the forage available to grazing animals, and the percent deviation in forage relative to historical weather data (1961-2002). The historical data is based on the CHARM algorithm (Collaborative Historical African Ranfall Model) developed by Funks et al. (2003), corresponding to each monitoring point.

A model that uses both past values of the time series and past shocks is called an AutoRegressive Moving-Average (ARMA) process. An ARMA model of a differenced series is called an ARIMA model, where the I stands for Integrated, because the output needs to be integrated to forecast the original series. As described by SAS (1999), the ARIMA procedure analyzes and forecasts equally spaced univariate time series data using the ARIMA model. An ARIMA model popularized by Box et al. (1994) predicts a value in a response time series as a linear combination of its own past values (autoregressive), past errors, shocks or random disturbances (moving average), and

Global Livestock Collaborative Research Support Program
University of California - Davis n 258 Hunt Hall n Davis, California 95616 USA
Phone 530-752-1721 n Fax 530-752-7523 n E-Mail glcrsp udavis.edu n Web glcrsp.ucdavis.edu

current and past values of other related time series (covariate).

Both the PHYGROW forage output and Normalized Difference Vegetation Index (NDVI) data were subjected to “white noise” or “prewhitening” analysis, which removed the intrarelationship in the individual series and inherent noise in the data series. This allowed accurate assessment of the interrelationship between the input and the output series. Each data series was then made stationary by applying the appropriate differencing from its ARIMA model. Seasonal dependency patterns were identified, and given the variability in weather patterns over the region. An annual circle produced the best correlation. We removed serial dependency by differencing the series to identify the hidden nature of seasonal dependencies in the series.

The denoised NDVI and forage data was then subjected to the second step of parameter estimation using the function minimization procedure (nonlinear estimation), so that the sum of squared residuals was minimized. The estimates of the parameters were used in the last stage (forecasting) to calculate new values of the series (beyond those included in the input data set) and confidence intervals for those predicted values. The estimation process was performed on transformed (differenced) data. Before the forecasts were generated, the series was integrated (integration is the inverse of differencing) so that the forecasts were expressed in values compatible with the input data.

Preliminary Findings

The ARIMA procedure allows modeling of two correlated time series of data. Figure 1 provides an example of a simple one-to-one relationship between forage standing crop and the satellite-derived NDVI for a given 8 x 8 km grid in East Africa. Given the diversity in landscapes, topography, and vegetation types of East Africa, creation of a spatial and time series data proxy was of paramount importance for developing forecasting capacity in the LEWS project.

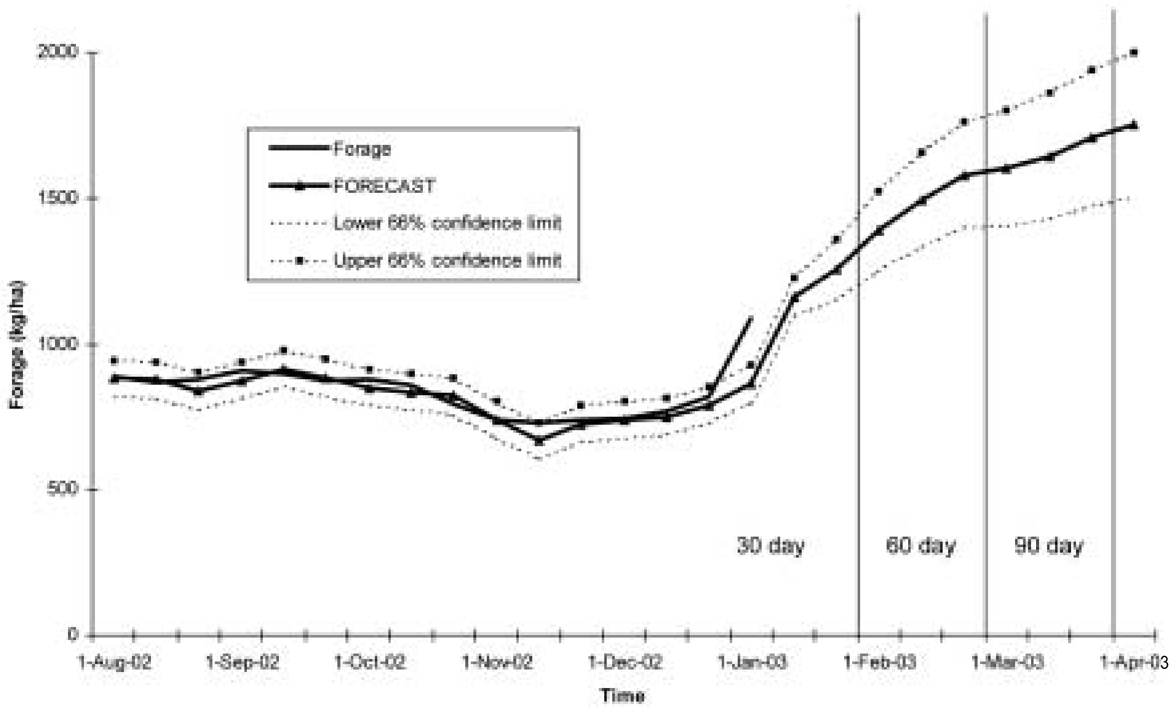
The ARIMA time series forecasting methodology appeared to provide suitable projections well within normal field sampling error for most of the 300 sites within the LEWS study region in East Africa. R^2 and SEP (kg/ha) values for 8,820 projections for the 30, 60, and 90-day forecast of grazable standing crop were 0.93/141, 0.81/206, and 0.71/259 respectively (Figure 2).

Practical Implications

Pastoralists, NGO advisors, and government relief agencies have all indicated to the LEWS team that they want to know what current forage conditions are in terms of deviation from historical grazed forage supply, and what those conditions will likely be over the next 90 days, with frequent and timely updates. Prior analysis has indicated that the LEWS technology suite can indeed provide forage condition analyses every 10

Figure 1: Sample relationship between forage and the corresponding normalized difference vegetation index (NDVI).

Figure 2: Forage forecast showing 30, 60, and 90-day projections.



days with graphs, maps, and written reports distributed over the Internet and over WorldSpace Radios to over 400 organizations in East Africa (http://cnrit.tamu.edu/aflews). The remaining piece of the puzzle was to provide forecasting information within normal sampling error suitable for decision-making. The analysis conducted herein indicates that near-term forecasting up to 90 days is possible and will provide a valuable additional piece of information to extend the time by which the LEWS information system can have an impact on the decision-making processes concerning livestock management in pastoral communities within East Africa. Our research team continues to work with other forecasting organizations, such as Columbia University's International Research Institute for Climate Prediction to extend our forecasting capacity beyond 90 days.

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Further Reading/Resources

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http://cnrit.tamu.edu/aflews - Analysis Portal for Livestock Early Warning System for East Africa.

http://cnrit.tamu.edu/rsg/rainfall/rainfall.cgi - Weather Access Portal for African Weather Data Used in the LEWS Program.

About the Authors: Dr. Robert Kaitho, Dr. Abdi Jama, and Mr. Jay Angerer are assistant research scientists and Dr. Jerry Stuth is a Kelleher Professor, all in the Department of Rangeland Ecology and Management. William Mnene is a Rangeland Ecologist with the Kenya Agricultural Research Institute - Kiboko. Margaret Kingamkono is an Animal Scientist at the Selian Agricultural Research Institute in Arusha, Tanzania. Joseph Ndungu is a Research Scientist at KARI - Marsabit. Angello Mwilawa is a Livestock Specialist at the Ministry of Water and Livestock Development in Mpwapwa, Tanzania. Jane Sawe is an Assistant Lecturer in Animal Science at Egerton University in Kenya. Steven Byenkya is a Research Scientist in the National Agricultural Research Organization of Uganda. Elizabeth Muthiani is a Research Scientist at the KARI - Kiboko research center. Ezekiel Goromela is a Livestock Research Scientist at the Ministry of Water and Livestock Development in Mpwapwa, Tanzania.

The GL-CRSP Livestock Early Warning System Project (LEWS) was established in 1998 and conducts research and training in the use of the livestock early warning system, actively monitoring sites in Ethiopia, Kenya, Tanzania, and Uganda. The system detects changes in forage supply and livestock well-being in pastoral regions of East Africa and reports on emerging conditions to both national, international, and community-based early warning and monitoring organizations. The project is led by Dr. Jerry Stuth, Texas A&M University. Email contact: j-stuth@cnrit.tamu.edu.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East Africa, Central Asia and Latin America.

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